

METAL -INSULATOR-METAL CAPACITOR STRUCTURE

FIELD OF THE INVENTION

[0001] The present invention relates to integrated circuit and semiconductors and, more particularly, to a metal-insulator-metal capacitor structure having an increased capacitor volume without occupying extra die area, and a capacitor dielectric material of a high dielectric constant.

BACKGROUND OF THE INVENTION

[0002] Advances in integrated circuit (IC) technology have involved the fabrication of multiple layers of interconnects. Interconnects are formed on top of the substrate and connect various functional components of the substrate and other electrical connections to the IC.

[0003] Capacitors are incorporated between the interconnect layers in order to maximize the use of the space between the interconnect layers. The capacitors formed between the interconnect layers are preferably of a metal-insulator-metal (MIM) construction, as the conductors of the interconnect layers are metal in construction. MIM capacitors may be used to store a charge in a variety of semiconductor devices, that may be utilized in the IC.

[0004] Conventional MIM capacitor structures consume a relatively large percentage of the surface area of a semiconductor wafer or chip because they are typically constructed as a large flat structure formed by a low dielectric constant (k) silicon dioxide or nitride capacitor dielectric layer sandwiched between upper and lower metal electrodes, positioned parallel to the wafer surface. In order to reduce the area of these structures, the prior art has attempted to replace the low k material used for the capacitor dielectric layer with high k materials such as BaTiO₃ and SiTiO₃. However, such high k materials do not adhere well to the metal electrodes,

which are still relatively large, thereby leading to delaminations in the capacitor structures.

Hence, the capacitor dielectric in conventional MIM capacitor structures is limited to dielectric materials with high dielectric constants, such as BaTiO₃ and SiTiO₃.

[0005] Accordingly, a MIM capacitor structure is needed that utilizes wafer area more efficiently than conventional MIM capacitor structures and allows the use of capacitor dielectrics with high dielectric constants.

SUMMARY OF THE INVENTION

[0006] According to a first aspect of the invention, a capacitor comprising an electrically conductive plate, an electrically conductive segmented plate defining at least two electrically conductive plate segments, a first capacitor dielectric disposed between the plate and the segmented plate, at least one electrically conductive interconnect coupling one of the at least two plate segments to the plate, and a second capacitor dielectric disposed between the at least two plate segments.

[0007] According to a further aspect of the invention, a capacitor comprising an electrically conductive plate, an electrically conductive segmented plate defining a first plurality of electrically conductive plate segments and a second plurality of electrically conductive plate segments, a first capacitor dielectric disposed between the plate and the segmented plate, at least one electrically conductive interconnect coupling each of the plate segments of one of the first and second plurality of plate segments to the plate, and a second capacitor dielectric disposed between the plate segments.

[0008] According to another aspect of the invention, a method of fabricating a capacitor, comprising forming an electrically conductive plate, forming a first capacitor dielectric over the

plate, forming at least one via in the first capacitor dielectric, forming an electrically conductive segmented plate over the first capacitor dielectric, the segmented plate defining at least two electrically conductive plate segments, the at least one via electrically coupling one of the at least two plate segments to the plate, and forming a second capacitor dielectric between the at least two plate segments.

[0009] According to still another aspect of the invention, a method of fabricating a capacitor, comprising forming an electrically conductive plate, forming a first capacitor dielectric over the plate, forming a plurality of vias in the first capacitor dielectric, forming an electrically conductive segmented plate over the first capacitor dielectric, the segmented plate defining a first plurality of electrically conductive plate segments and a second plurality of electrically conductive plate segments, the vias electrically coupling the conductive plate segments of one of the first and second plurality of plate segments to the plate, and forming a second capacitor dielectric between the plate segments.

BRIEF DESCRIPTION OF THE DRAWINGS

[0010] FIG. 1A is an elevational view of an illustrative embodiment of a MIM capacitor structure of the present invention.

[0011] FIG. 1B is a top plan view of the MIM capacitor structure of the present invention.

[0012] FIGS. 2-8 are perspective views depicting a method for fabricating a MIM capacitor structure according to an illustrative embodiment of the present invention.

[0013] FIG. 9 is a flow chart for the method of the invention.

DETAILED DESCRIPTION OF THE INVENTION

[0014] The invention is a metal-insulator-metal (MIM) capacitor structure and fabrication method. The MIM capacitor structure of the invention has increased capacitor volume without occupying extra die area, and allows the use of a capacitor dielectric material of a high dielectric constant, such as BaTiO_3 , which can have a dielectric constant of up to 11 at room temperature.

[0015] FIGS. 1A and 1B shown an illustrative embodiment of the MIM capacitor structure of the present invention. The capacitor structure, denoted by numeral 100, includes a solid continuous metal plate 110, a segmented metal plate 130 of spaced apart metal plate segments 131, a capacitor dielectric 120 disposed between the continuous metal plate 110 and the segmented metal plate 130, and a capacitor dielectric 140 disposed between the metal plate segments 131 of the segmented metal plate 130. The metal plate segments 131 may be formed as alternating thick (T1 in FIG. 1A) and thin (T2 in FIG. 1A) metal plate sections 131a and 131b. Every other metal plate segment 131 (the thin metal plate segments 131b in the shown embodiment) of the metal segmented plate 130 is electrically coupled to the continuous metal plate 110 by at least one electrically conductive interconnect 121, or row of electrically conductive interconnects (not visible), which extend through the capacitor dielectric 120. The continuous metal plate 110 and interconnect-coupled metal plate segments 131 (the thin metal plate segments 131b in the shown embodiment) of the segmented metal plate 130 form one capacitor electrode of the capacitor structure, and the other metal plate segments 131 (the thick plate segments 131a in the shown embodiment) of the segmented metal plate 130 form the other capacitor electrode of the capacitor structure.

[0016] As oriented in FIG. 1A, the continuous metal plate 110 and the metal plate segments 131 of the segmented metal plate 130, not associated with the interconnects 121 (the thick metal plate segments 131a in the shown embodiment), form a plurality of “vertical” capacitors 150. The metal plate segments 131 of the segmented metal plate 130, not associated with the interconnects 121 (the thick metal plate segments 131a in the shown embodiment), and the interconnect-coupled metal plate segments 131 (the thin metal plate segments 131b in the shown embodiment) of the segmented metal plate 130 form a plurality of “horizontal” or “lateral” capacitors 160. The vertical and lateral capacitors 150 and 160 may be coupled together in parallel to increase the capacitance of the overall MIM capacitor structure 100.

[0017] The segmented metal plate 130 maximizes the electrode area of this plate and allows the space between the segments 131a and 131b to be filled with high dielectric constant (K) materials. The side walls of the plate segments 131a and 131b effectively increase the total capacitor area, and the high K materials disposed between the plate segments 131a and 131b increases the capacitor volume.

[0018] The MIM capacitor structure of the invention may be incorporated in an integrated circuit (IC) (not shown) of the type having multiple metallization layers for interconnections. The interconnections may be built or layered above one another and may overlie a substrate (not shown) that serves as the foundation for the IC and its functional components such as transistors and other semiconductor devices.

[0019] A method for fabricating the above MIM capacitor structure according to an illustrative embodiment of the present invention will now be described with reference to the perspective views of FIGS. 2-8 and the flow chart of FIG. 9. Referring initially to step 300 of FIG. 9, a first metal layer 210 is deposited over a substrate 200 as shown in FIG. 2. The

substrate 200 may be an inter-metal dielectric layer, which has been patterned with contact vias or damascene metal lines, depending upon the IC technology used. The first metal layer 210 may be formed. The first metal layer 210 forms the solid continuous metal plate 110 of the MIM capacitor structure shown in FIG. 1A. The substrate 200 may comprise a semiconductor material, such as silicon, and may be covered by an insulating layer (not shown). The substrate 200 may also include circuits, transistors, and other semiconductor devices (not shown). The first metal layer 210 may comprise one or more layers of metal, such as Ti-TiN-AlCu-TiN or Ti-TaN-Cu, depending upon the integrated circuit technology used. The metal layer 210 may be deposited by processes including, without limitation, PVD (physical vapor deposition), CVD metal or plating. The first metal layer 210 may be deposited to a thickness of approximately 200 to 5,000 angstroms.

[0020] In step 310 of FIG. 9, a layer 220 of a first capacitor dielectric is deposited over the first metal layer 210 as shown in FIG. 3. The capacitor dielectric layer 220 forms the capacitor dielectric 120 between the continuous metal plate 120 and the segmented metal plate 130 of the MIM capacitor structure shown in FIGS. 1A and 1B. The capacitor dielectric layer 220 may comprise one or more layers of silicon oxide, silicon nitride, plasma enhanced nitride (pe-nitride) and oxy-nitride or various combinations thereof, deposited, for example, using PVD sputtering. The capacitor dielectric layer 220 may be a relatively thin layer approximately 50 to 500 angstroms, depending upon the capacitance desired and the dielectric material or materials used.

[0021] In step 320 of FIG. 9, one or more rows of at least one via 230 are formed in the capacitor dielectric layer 220 as shown in FIG. 4. The vias 230 may be formed using a

conventional via plasma etch process. The first metal layer 210 can be used as an etch stop for the via etch process.

[0022] In step 330 of FIG. 9, a second metal layer 240 may be deposited over the capacitor dielectric layer 220 as shown in FIG. 5. The second metal layer 240 conformally fills the vias 230. The metal filled vias 230 form the electrical interconnects 121 of the MIM capacitor structure shown in FIGS. 1A and 1B. The vias may also be filled with a metal or other electrically conductive material in a separate fabrication step, prior to the deposition of the second metal layer 240, if desired. The second metal layer 240 may comprise one or more layers of metal such as Ti-TiN-AlCu-TiN or Ti-TaN-Cu, depending upon the integrated circuit technology used. The second metal layer 240 may be deposited by processes including, without limitation, PVD (physical vapor deposition), CVD metal or plating. The second metal layer 240 is typically thicker than the first metal layer 210 at approximately 500 to 8,000 angstroms to increase the vertical area of the metal plate segments that will be formed therefrom.

[0023] In step 340 of FIG. 9, the second metal layer 240 is etched to form metal segments 241 as shown in FIG. 6. The etched second metal layer 240 forms the segmented plate 130 of the MIM capacitor structure shown in FIGS. 1A and 1B. Etching can be accomplished using conventional photolithographic and metal etching processes, such as reactive ion etching. The capacitor dielectric layer 220 functions as an etch stop layer for this process. The spaces 250 formed between the segments 241 are typically about 50 to 450 in thickness.

[0024] In step 350 of FIG. 9, a layer 260 of second capacitor dielectric may be conformally deposited over the second metal layer 240 as shown in FIG. 7. The capacitor dielectric layer 260 fills the spaces 250 between segments 241. The capacitor dielectric layer 260 may comprise one or more layers of a high dielectric constant material, such as BaTiO₃, SiTiO₃,

or various combinations thereof, deposited, for example, using PVD sputtering. The capacitor dielectric layer 260 may be a relatively thin layer approximately 50 to 500 angstroms, depending upon the capacitance desired and the dielectric material or materials used.

[0025] In step 360 of FIG. 9, the capacitor dielectric layer 260 may be etched back to the metal segments 241 of the second metal layer 240 as shown in FIG. 8. Etching may be performed using a conventional etch-back process, such as bromide plasma. The metal segments 241 of the second metal layer 240 can be used as an etch stop for the etch-back process. The etched capacitor dielectric layer 260 forms the capacitor dielectric 140 disposed between the metal plate segments 131 of the segmented metal plate 130 of the MIM capacitor structure shown in FIGS. 1A and 1B.

[0026] While the foregoing invention has been described with reference to the above embodiment, various modifications and changes can be made without departing from the spirit of the invention. Accordingly, all such modifications and changes are considered to be within the scope of the appended claims.